AACL BIOFLUX
Aquaculture, Aquarium, Conservation & Legislation
International Journal of the Bioflux Society

Coral Tree Nursery©: An innovative approach to growing corals in an ocean-based field nursery

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Abstract. Successful mariculture of stony corals has been demonstrated extensively for the past ten to fifteen years, mostly in the tropical Pacific Ocean for the global marine ornamental aquarium market. Many different methods have been used to asexually fragment and grow branching stony corals, but all utilize a two-dimensional grow out design, primarily horizontal and affixed on some sort of disk like structure. To maximize growing surface and take advantage of the three dimensional water column space above the sea floor, the Coral Restoration Foundation has developed a novel new technique, the Coral Tree Nursery©, which has proven to be very effective at both increasing growth over previous methods and reducing disease and damage risks from wave forces.
Key Words: coral mariculture, coral aquaculture, coral, coral conservation, reef restoration.

Introduction. The mariculture of corals through asexual fragmentation has been a very effective strategy for reproducing corals for both ornamental and conservation purposes. The methods developed have involved land-based culture, as well as field nurseries. Both have proven successful on a small scale, but neither has successfully been able to produce massive quantities of second and third generation corals suitable for sale or restocking projects. Land-based production systems have limitations when it comes to high volume capacity, are expensive to maintain, and are more vulnerable to catastrophic losses due to equipment failure, disease, and parasites. Field based, or *in situ* nurseries, using traditional designs have faced enormous maintenance challenges, and are vulnerable to hurricanes, terrestrial run off, and conflicting user activities such as fishing, trapping, or boating.

One of the more common methods for *in situ* culturing stony corals involves cutting/fragmenting a small piece of coral (5-10 cm in length) and attaching the coral to a round disk or "plug" with underwater adhesive or wire/string (Ellis & Ellis 2001). The "disk" is then attached to a mounting "rack" and is typically raised off the ocean floor using some sort of readily available material such as steel rebar or concrete blocks. This method is somewhat labor intensive to set up and maintain, and is vulnerable to weather disturbances and predation.

Another popular nursery design to grow coral for restoration purposes involves suspending the corals over the sea floor by either twisting the coral fragment into ropes, or hanging the coral from wires, line, or rope attached to stacked horizontal lines (Bowden-Kerby 1997, 2001; Quinn 2005). These methods allow the corals to dangle in the water, freeing the coral to grow in all directions. Maintenance requirements for this method are greatly reduced, and growth and survival rates appear to be significantly higher than the disk nursery method. However, both of these designs (twisted in ropes and hanging from lines) pose entanglement risks to large marine life (primarily sea turtles), and are prone to sagging and tangling as the corals become larger and heavier.

Still another method, called a mid water coral nursery, blends the disk design with the suspended line nursery design to come up with a floating net structure that holds racks of disks or pedestal mounted corals (Rinkevich 1995, 2000; Epstein et al 2001; Shafir et al 2006). This

design is beneficial in areas where the bottom is too deep, or the area has an unsuitable bottom (grass or mud). This method, however, is vulnerable to damage from storms, requires maintenance, and also poses possible entanglement hazards to marine life.

The innovative floating Coral Tree Nursery© design was developed to mariculture Staghorn Coral, *Acropora cervicornis* (Lamarck, 1816) but can be used to grow a variety of coral species. The design set out to resolve some of the short-comings discussed above with the other popular coral nursery designs. The Coral Tree Nursery© is a simple framework that resembles the shape of a tree. Corals are fragmented as in previous methods, but then simply attached to the coral tree arms using wire or monofilament line. The Coral Tree Nursery is tethered to the sea floor and buoyed with a subsurface floatation device that can be moved up and down the water column as the need arises. For sandy or sea grass bottoms a single Duckbill® anchor pounded in the sand or sediment will hold the tree in place, and for a rocky bottom the tether line can be tied to an outcrop or an eye bolt that has been epoxied/cemented into the ground.

Due to the subsurface flotation device, the Coral Tree Nursery© floats in the water column and is able to move with storm generated wave surges. This dissipates wave energy preventing damage to the tree structure or corals. Maintenance is significantly reduced, as surface area for nuisance algae growth is limited. In addition, the Coral Tree Nursery© nursery design is suitable for many different habitats and can be installed by one person.

Coral Tree Nursery© Design. The objective of the Coral Tree Nursery© is to address the limitations of the present nursery designs. The Coral Tree Nursery© is superlative when compared to the other methods due to its low cost design that utilizes materials commonly available in developing countries. There are presently two designs in use for the Coral Tree Nursery©.

The first design uses SCH 40 PVC Pipe (19mm diameter) and consists of a PVC central column with PVC arms connected to the column using PVC cross fittings (Figure 1). Recommended column length is 1.3m with alternating 0.5 m PVC arms that spaced 13cm apart. This structure will hold 20 individual arms, each capable of holding up to 8 hanging corals spaced 5cm apart. Corals can be hung from the arms using thin gauge vinyl coated wire or monofilament, which can be attached to the armsusing looped cable ties, stainless steel cotter pins placed in pre drilled holes, or by passing the wire/monofilament through pre-drilled holes (Figure 2).

Variations of this design would include:

- Thicker diameter PVC pipe can be used for
- larger structures, and longer central columns or
- cross arms can be used to increase capacity, but additional floatation may be required for larger structures.
- A larger diameter central column that is drilled with 9.5mm holes for the cross arms, eliminating the need for PVC cross fittings.
- Drilling 5mm holes in the cross arms for inserting "frag plugs" for growing corals on disks on top
- of the cross arms, as opposed to hanging below the
- arms from wires/monofilament lines (Figure 3).

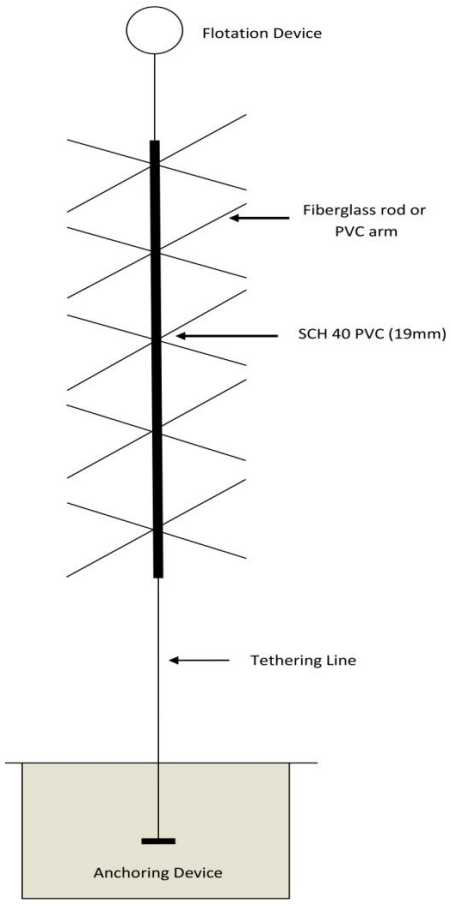

Figure 1. Typical tree nursery design

The second design uses fiberglass rods (9.5mm diameter) for the cross arms, instead of PVC. The fiberglass rods are passed directly through pre-drilled holes in the central PVC pipe, eliminating the need for PVC "crosses". Corals can be attached to the fiberglass arms using wires or monofilament that is passed through small, evenly spaced holes that are pre-drilled through the fiberglass rods. The optimal configuration using these materials is similar to the one using just PVC (1.3m central column with alternating arms spaced evenly at 13cm), but for the arms, a single 1m rod passed through the central column replaces two 0.5M PVC arms glued to PVC crosses (Figure 3). Additional capacity can be obtained by using a longer central column and longer arms, but additional floatation will be required and sturdier materials may be necessary.

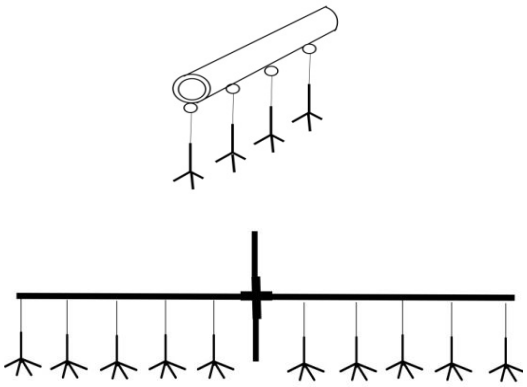

Figure 2. Coral hanging arrangement

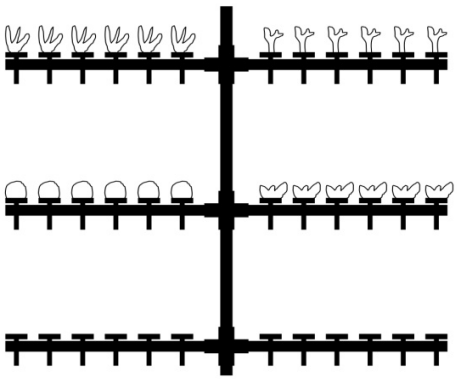

Figure 3. Coral plug arrangement

Tethering Options. There various ways to attach the Coral Tree Nursery© to the seafloor or reef. For sandy or grassy bottoms, Duckbill® anchors and steel rebar rods driven several feet into the bottom provide ideal anchoring devices with minimal impact. For hard bottom habitats, a stainless steel eye-bolt that has been epoxied into the hard bottom works well. In some cases, the Coral Tree Nursery© can be simply tied directly to the reef. For securing the Coral Tree Nursery© to the anchor point, polypropylene rope, nylon rope, or monofilament cables can be used. Slip knots can be employed to allow the Coral Tree Nursery© to be easily raised or lowered in the water column.

Floatation Options. The ability to keep the Coral Tree Nursery© erect and capable of supporting growing corals is directly related to the floatation device used. A Styrofoam or polystyrene ball or float (min. 15.24 cm diameter) is recommended. Larger floatation devices can be used but create drag and are more adversely influenced by current and tidal flow. If the corals are allowed to grow large, an additional float can be added as needed. Plastic bottles (2 liter or more) can also be used. The utilization of two designs allows for construction improvisation based on readily available materials. Both designs have proven to be very effective in the growth of *A. cervicornis*, but could be applied to a variety of stony coral species, especially branching growth forms like *Acropora sp., Montipora sp., Stylophora sp.,* and *Seriatapora sp* to name a few. The concept of line or floating nurseries is not new and has been used extensively throughout the South Pacific and Asia for a variety of commercial species, such as sponges, pearl oysters, corals, algae and giant clam juveniles. The innovative application of the floating nursery system for coral through this specific design is completely new. The recommended depth for using the Coral Tree Nursery© to culture hermatypic scleractinians corals is 5-10m. The ability to raise and lower

the Coral Tree Nursery© gives much flexibility in its deployment depth. This allows divers to work using a snorkel, hookah or SCUBA without the need for decompression and provides enough vertical water column to adjust the working height for ideal conditions.

Advantages. The Coral Tree Nursery© is unique from previous designs and has numerous strengths including:

i. Incorporates better use of vertical water column thereby reducing drag and balancing weight distribution more evenly. This significantly reduces drag and is much less susceptible to damage from wave action. The movement of the entire Coral Tree Nursery with tidal flow and wave energy also keeps the structure intact longer by reduced stress on the framework versus a fixed or more horizontal floating structure.
ii. Minimal impact on sensitive seafloor habitats, such as sea grasses and coral beds.
iii. Portability since it can be easily moved by one person to another location underwater or above water.
iv. Adjustable height as it can be raised for more/less sunlight, reduced wave impacts and ideal temperature exposure during seasonal variations.
v. Corals exhibit increased growth rates due to increased water flow and lack of a substrate holdfast requirement.
vi. Corals experience lower mortality from disease and benthic predators, such as snails, worms, and damselfish
vii. Maintenance is limited by reduced surface area for nuisance algae versus corals attached to a substrate.
viii. Entanglement risks to marine life (versus a line, rope, or net nursery) is minimized
ix. Low cost and lightweight materials for small boat transport and installation

Conclusion. The Coral Tree Nursery© design has solved many of the problems associated with existing benthic and line nursery techniques. The availability of materials used and low cost makes it an ideal method for deployment almost anywhere in the world. The limited footprint, simple design and portability further exemplify its practicable use. Reef restoration is a valuable tool to help bring back degraded coral reefs that have been damaged by either direct or indirect anthropogenic factors. The conservation of valuable coral species directly benefits from such restoration efforts and should be encouraged. By using the Coral Tree Nursery, habitats that are vital to maintaining fish populations for food as well as tourism can be re-established and preserved.

Acknowledgements. CRF would like to thank the Florida Keys National Marine Sanctuary (FKNMS) for their continued support of the coral nursery and restoration program. Funding also provided by the Disney Wildlife Conservation Fund and the American Reinvestment and Recovery Act (ARRA) administered through the National Oceanic and Atmospheric Administration (NOAA) and The Nature Conservancy (TNC). The author KN is the inventor of the Coral Tree Nursery© and President of the Coral Restoration Foundation, Inc. a not for profit 501(c)(3) corporation.

References

Bowden-Kerby W. A., 2001 Coral transplantation modeled after natural fragmentation processes: low-tech tools for coral reef restoration and management. PhD thesis, University of Puerto Rico at Mayagüez 195pp.

Bowden-Kerby A., 1997 Coral transplantation in sheltered habitats using unattached fragments and cultured colonies. Proc 8th Int Coral Reef Sym **2**:2063-2068.

Ellis S., Ellis E., 2001 Recent Advances in Lagoon-based Farming Practices for Eight Species

of Commercially Valuable Hard and Soft Corals - A Technical Report. CTSA Publication No. 147., 63 pp.
Epstein N., Bak R. P. M., Rinkevich B., 2001 Strategies for gardening denuded coral reef areas: the applicability of using different types of coral material for reef restoration. Restor Ecol **9**:432-442.
Quinn N. J., 2005 Coral Reef Gardening Project under USAID's Coastal Water Quality Improvement Project – Phase II (CWIP2) Final Report, Discovery Bay Marine Laboratory, UWI 20 pp.
Rinkevich B., 1995 Restoration strategies for coral reefs damaged by recreational activities: the use of sexual and asexual recruits. Restore Ecol **3**:241-251.
Rinkevich B., 2000 Steps towards the evaluation of coral reef restoration by using small branch fragments. Mar Biol **136**:807-812.
Shafir S., Rijn J. V., Rinkevich B., 2006 Steps in the construction of underwater coral nursery, an essential component in reef restoration acts. Mar Biol **149**:670-687.

Received: 28 April 2011. Accepted: 28 May 2011. Published online: 10 June 2011.
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How to cite this article:
Nedimyer K., Gaines K., Roach S., 2011 Coral Tree Nursery©: An innovative approach to growing corals in an ocean-based field nursery. AACL Bioflux **4**(4):442-446.